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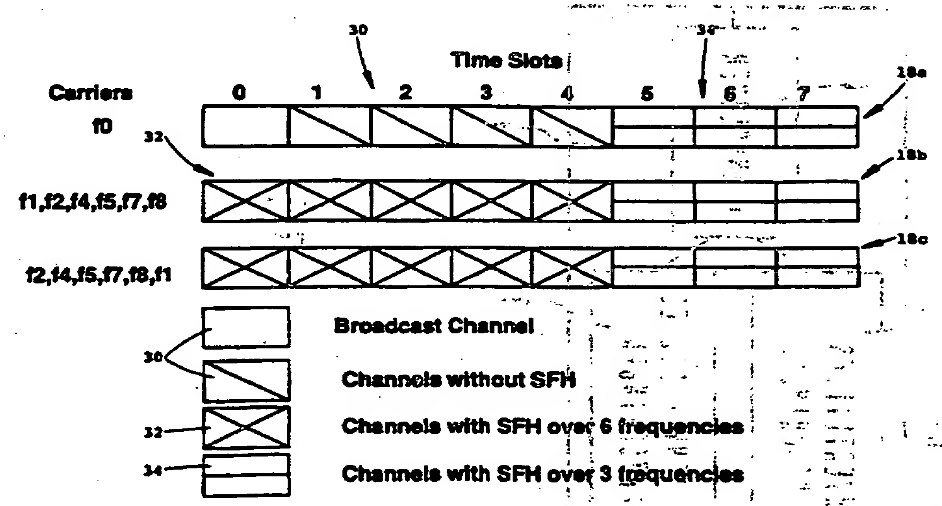

(57) Abstract

A cellular telecommunications method for use in a cellular telecommunications network having at least one cluster of adjoining cells, including allocating a respective control channel frequency to each cell for transmitting a control channel in a cell, allocating a set of frequencies to the cluster for use by the cells, with each cell having a respective subset of said set, and swapping between the frequencies of a subset for first traffic channels of a cell (34) and swapping between the sets of frequencies in a cluster for second traffic channels of the cell (32). The control channel frequency is allocated to third traffic channels of the cell (30). Calls are selectively allocated to one of the traffic channels based on transmission characteristics of the call. The quality of service provided by the second channels is greater than that of the first channels which again is greater than that of the quality of service provided by the third channels. A cellular network, in particular a GSM network, has base stations which are adapted to provide the first, second and third traffic channels by executing intracell slow frequency hopping and intercell frequency allocation swapping.

no swapping control frequencies

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A CELLULAR TELECOMMUNICATIONS METHOD AND NETWORK

This invention relates to a cellular telecommunications method and network, and, in particular, a method for dynamically allocating communication channels in a cellular network.

An important factor in considering the performance of a cellular telecommunications network relates to the idea of reusing transmission frequencies in separated areas or cells. This cellular concept permits a large subscriber capacity within a limited allocation of frequency spectrum. For example, only a certain bandwidth within the radio frequency portion of the electromagnetic spectrum is allocated for cellular telecommunications, and each communications carrier requires some fraction of the total available bandwidth. Consequently, only a limited number of carriers can coexist in a single area due to the limited allocation of bandwidth.

An important consideration in cellular communications systems is co-channel interference, which refers to interference between signals from different cells which may be transmitting on the same carrier frequency. Co-channel interference is a function of the distance between the interfering cells and the transmission power and direction of transmission from those cells. Clearly, if every cell in a cellular network were to use all available carrier frequencies then a large amount of co-channel interference would result, particularly between signals from adjacent cells.

In order to alleviate the problem of co-channel interference, a cellular network can be arranged into clusters of adjoining cells, such that the cells in a particular cluster each transmit on different carrier frequencies. Each cell can be allocated a subset of carrier frequencies from the total number of available frequencies. The cells in a single cluster may therefore collectively utilise all of the available frequencies, but since the

adjoining cells within the cluster each use different carrier frequencies they do not interfere with each other. Furthermore, taking into account the spatial relationship between adjacent clusters, the allocation of frequencies within a cluster can be arranged so that the frequencies in a cell of one cluster which is adjacent to a cell of another cluster do not interfere.

In addition to co-channel interference, another factor which influences the quality of signal transmission are the propagation conditions for the radio frequency signals. In particular, propagation conditions and phenomena which arise therefrom, such as multi path fading, are dependent upon the transmission frequency, and vary substantially from one carrier frequency to another. A technique known as frequency hopping can be used to reduce the effects of frequency dependent phenomena, by periodically changing the transmission frequency for a channel in a particular cell. For example, if a cell has an allocation of three carrier frequencies then the transmitting base station can periodically switch between frequencies during transmission of a particular signal. Therefore, if one of the carriers is subject to poor propagation conditions during transmission of the signal then the signal quality for the channel is only affected one third of the time on average. In digital cellular communication systems, frequency hopping facilitates signal processing and diminishes the error probability after error correction decoding. It has been found that the signal quality which can be achieved increases if more frequencies are available for frequency hopping. Unfortunately, the total number of frequencies available in a cluster, and therefore in the network as a whole, is limited and the number of frequencies allocated to a given cell can only be a fraction of this amount.

In accordance with the present invention there is provided a cellular telecommunications method for use in a cellular telecommunications network having at least one cluster of adjoining cells, including:

allocating respective control channel frequencies to said cells for transmitting a control channel in a cell;

allocating at least one other different frequency to each cell;

swapping between the frequencies allocated to said cells, except the control

channel frequencies, for at least one traffic channel.

The present invention also provides a cellular telecommunications network having at least one cluster of adjoining cells, said cells each including:

a first transceiver for transmitting a control channel in a respective control channel frequency;

a second transceiver for transmitting at least one traffic channel at a different frequency allocated to the cell; and

control means for controlling said second transceiver to swap between the frequencies allocated to said cells, except the control channel frequencies, for said at least one traffic channel.

The present invention further provides a a cellular telecommunications method having signals for transmission within a cell organised in time division multiplexed channels, said method including transmitting first channels utilising a first number of transmission frequencies; and transmitting second channels using a second number of transmission frequencies.

The present invention also provides a cellular telecommunications network including:

a cluster of cells having a set of transmission frequencies; and

a base station in each cell of said cluster adapted for transmission of signals on first channels within the cell using a first number of said frequencies and on second channels within the cell using a second number of said frequencies.

The present invention further a cellular telecommunications method for use in a cellular telecommunications network having at least one cluster of adjoining cells, said cells being allocated different respective sets of different transmission frequencies, said method including:

intracell frequency hopping by swapping the allocated frequencies within said cells; and

intercell frequency allocation swapping by swapping said sets of frequencies

between the cells.

The present invention also provides a cellular telecommunications network including at least one cluster having adjoining cells provided by corresponding base stations, said cells being allocated different respective sets of different transmission frequencies and the base stations having control means for controlling intracell frequency hopping by swapping the allocated frequencies within said cells, and controlling intercell frequency allocation swapping by swapping said sets of frequencies between the cells.

Preferred embodiments of the present invention are described hereinafter, by way of example only, with reference to the accompanying drawings, wherein:

Figure 1 is a schematic diagram of a cellular telecommunications network;

Figure 2 is a schematic diagram of a cluster of cells of the cellular network;

Figures 3A to 3C are tables showing transmission frequency allocation in a conventional cellular network cluster with equal number of frequencies in each cell;

Figures 4A to 4C are tables showing transmission frequency allocation in a conventional cellular network employing a cyclic slow frequency hopping (SFH) strategy;

Figures 5A to 5C are tables showing transmission frequency allocation according to a preferred embodiment for the case of equal number of frequencies in each cell and cyclic slow frequency hopping;

Figure 6 is a diagram of transmissions in a GSM digital cellular network;

Figure 7 illustrates mapping of logical channels to physical channels in a GSM network using neither SFH nor frequency allocation swapping (FAS);

Figure 8 illustrates mapping of logical channels to physical channels in a GSM network using cyclic SFH but not FAS;

Figure 9 illustrates an example of mapping of logical channels to physical channels in a network employing cyclic SFH together with cyclic FAS according to a preferred embodiment;

Figures 10A and 10B show two clusters in a GSM network to illustrate the swapping of carrier frequencies between cells in accordance with a frequency allocation

swapping scheme;

Figure 11 is a table of carrier frequency allocations in cell A of the network in Figure 10A using SFH;

Figure 12 is a table of carrier frequency allocations in the network of Figure 10A utilising frequency allocation swapping amongst cells in a cluster according to a preferred embodiment;

Figure 13 illustrates channel distribution in TDMA frames for three carriers in a cell with various combinations of SFH and FAS according to another preferred embodiment;

Figure 14 is a table of transmission characteristics for various combinations of SFH and FAS;

Figure 15 is a graph of quality of service against distance for various combinations of SFH and FAS; and

Figure 16 is a diagram of SFH and FAS for the consecutive frames generated by three transceivers of a base station.

In Figure 1 there is shown a diagrammatic representation of the geographical layout of a cellular telecommunications network 2 which comprises nine cells 6 organised into three clusters 4 of three cells each. As can be seen from the drawing, each cell is considered to have a regular hexagonal shape, and the three cell clusters 4 each comprise three adjoining cells in a cloverleaf shape.

In the simplest cellular telecommunications network, each cell in the network would be provided with one or more carrier frequencies exclusively for use in that cell. As mentioned above, however, only a limited bandwidth in the electromagnetic spectrum is allocated by regulatory bodies for use in cellular telecommunications. Therefore, to allow for growth, both in terms of geographical area and the number of cells in a network, to cope with increasing communications traffic and to take advantage of the limited transmission power of cellular base stations, frequency reuse strategies are often employed. A frequency reuse strategy involves allocating the same transmission frequencies to a plurality of cells in the network. An important consideration then becomes the minimisation of co-channel interference brought about by transmissions

from different cells on the same frequency interfering with each other. The simplest way to reduce co–channel interference is to ensure that the distance between cells using the same carrier frequencies (the "reuse distance") is as large as possible. With this in mind, the idea of reuse clusters can be applied, wherein a cluster comprises a group of adjoining cells in which no two cells in the group are allocated the same carrier frequencies. Thus, with a reuse cluster topography, it is assured that the closest cell utilising the same carrier frequencies is at least as far away as the next cluster. In the early development of analogue cellular systems, cells with omnidirectional base station antennas were deployed, typically in reuse clusters of 12 cells.

It has been found that adverse propagation conditions can seriously degrade communications quality, by virtue of such phenomena as multipath fading. These conditions are frequency dependent, and thus may affect channels transmitted on one carrier frequency but not another. In order to alleviate these difficulties a scheme known as slow frequency hopping can be utilised, particularly in digital transmission systems. In a slow frequency hopping scheme, a particular channel is not assigned to a single carrier frequency, but rather the channel is transmitted using a plurality of different carrier frequencies in sequence. In this way, frequency dependent effects can be averaged out over a number of different carriers such that particular channels are not more seriously affected than others.

Referring to the network 2 shown in Figure 1, and the three cell cluster represented in Figure 2, the above described known cellular transmission techniques can be explained by way of example. Consider that the network 2 has available nine different carrier frequencies, f_1 to f_9. In the simplest case, each of the nine cells 1–1 to 3–3 shown in Figure 1 would be allocated only one of the available carrier frequencies f_1 to f_9. This scheme would result in no co–channel interference since each frequency is used only once in the network, but certain cells may experience detrimental multipath fading or other frequency dependent effects, whilst other cells may not. The network 2 is divided into clusters 4 of cells 6, resulting in three clusters of three cells each. The cluster 4 shown in Figure 2 illustrates one way in which the available frequencies f_1 to f_9 could be allocated in the cluster, with each cell allocated three separate carrier

frequencies. In general, the number of frequencies in each cell may not be equal. Each frequency would then be used by one cell in each cluster, with the frequency allocations within the clusters being arranged so that the cells of neighbouring clusters using the same frequencies are as spatially distant as possible. Figures 3A, 3B and 3C are tables of allocation of carrier frequencies to three communications channels in each of the cells 1 to 3 in Figure 2. As can be seen, each channel is allocated a single transmission frequency for the duration of the channel signal.

However, as mentioned above in a frequency allocation set up such as this, undesirable transmission effects may occur to one channel but not others, which effects can be averaged out over the channels and an additional gain in digital cellular communications systems may be achieved by way of slow frequency hopping. Tables 4A, 4B and 4C show a way in which slow frequency hopping could be implemented in the cluster of Figure 2, wherein each channel is transmitted on each of the carrier frequencies available in that cell, in a sequential manner. For example, channel 1 in cell 1 of the cluster begins transmission on frequency f_1, but hops to frequency f_2 and subsequently frequency f_3 during the course of transmission. The hopping of the frequencies may be carried out cyclically, as shown in Tables 4A to 4C, or may be random. It will be noted that of the three channels shown in each cell, at any one time (column) no two channels are transmitting on the same frequency. Of course this does not take into account time division multiplexing which may be implemented to transmit several channels on a single frequency as will be understood by those skilled in the art.

It has been found that the advantages gained by swapping carrier frequencies during transmission thereof are greater if more frequencies are used for each channel. In other words, if each cell has an allocation of six carrier frequencies, the average signal quality obtained over all of the channels in that cell is greater than if only three carrier frequencies are used, as in the above example. Accordingly, implementations of the present invention enable more frequencies to be used in each cell, without decreasing the reuse distance which is important for containment of co–channel interference. In brief, the frequency allocation scheme of the invention provides for intercell frequency swapping as well as, or in place of, intra cell frequency swapping. Thus frequencies can

be swapped between cells within a cluster in addition to between channels within a cell. In this way each channel may in fact be transmitted, in sequential portions, using all of the available network carrier frequencies, rather than only a fraction of them depending on the frequency reuse cluster size.

Tables 5A, 5B and 5C show an example of how frequency allocation swapping can be achieved, based on the example network described previously. As can be seen with reference to Table 5A, cell 1 of the cluster under consideration is initially allocated frequencies f_1, f_2 and f_3, as in the examples shown in Tables 3A and 4A. Furthermore, as in Table 4A, the channels are swapped between the three frequencies during the course of a cyclic slow frequency hopping period. However, at the end of the SFH period the frequency allocation of cell 1 is swapped with another of the cells in the cluster. In this case frequencies f_4, f_5 and f_6 are swapped from cell 2 to cell 1, frequencies f_7, f_8 and f_9 are allocated to cell 2 and the frequencies f_1, f_2 and f_3 are swapped from cell 1 to cell 3. At the end of the next SFH period the frequency allocations are again swapped. It can be noticed that the interference conditions do not change in the course of frequency swapping. With frequency allocations swapping with each SFH period, as in this example, the FAS cyclic period (number of SFH periods) of the frequency allocation swapping scheme corresponds to the number of cells in the cluster. It will be appreciated, however, that the frequency allocation swapping as between cells within a cluster, is quite separate from the slow frequency hopping within a cell, and therefore there is no requirement for frequency allocation swapping to be linked to the cyclic frequency hopping period. Indeed it is possible to implement the present invention without the provision of intracell frequency swapping as well as vice versa as shown in Tables 4A to 4C. It will also be appreciated that the frequency allocation swapping method can be used in conjunction with other techniques used in cellular networks such as time division multiplexing of channels on a single carrier, or sectored cells utilising directional antennas to reduce co-channel interference for different number of allocated cell frequencies and different number of frequencies swapped in one time.

One way in which digital cellular radio communications can be implemented is

according to the groupe speciale mobile (GSM) specification. Referring to Figure 6, communication between a base station (BS) 10 and a mobile station (MS) 12 of the GSM system involves the transmission of time division multiple access (TDMA) frames 14 which are each divided into eight 577 μs timeslots 16 which are referred to as physical channels. The TDMA frames are transmitted on a carrier, the frequency of which is dependant upon the frequencies allocated to the particular cell in which transmission takes place, as well as whether a frequency hopping scheme is used between frequencies within the cell and whether frequency allocation swapping is used amongst cells within a cluster.

Logical channels refer to channels of communication on a point-to-point basis, i.e. from the base station 10 to one mobile station 12, such as traffic channels (TCH), or on a point-to-multipoint basis, i.e. from the base station 10 to several mobile stations 12, such as a broadcast control channel (BCCH). Logical channels are multiplexed on the carriers in a cell by mapping them onto the physical channels of the TDMA frames. Further, the slow frequency hopping schemes described hereinabove can be thought of as a mapping of TDMA frame structures onto the RF carriers for the cell, whereas the frequency allocation swapping scheme of the invention can represent a mapping of carriers for each cell onto the various frequencies available within the cluster.

The GSM specification and the configuration and operation of GSM base stations 10 and mobile stations 12 is further described in the applicant's co-pending International Patent Application No. PCT/AU94/00561, which is herein incorporated by reference. The method of the preferred embodiment is executed by base stations 10 of the cells which have their controlling hardware and/or software adjusted to facilitate cyclic FAS and cyclic SFH as described hereinafter.

Figure 7 is a diagrammatic illustration of data for transmission in a cell having four carriers 18a, 18b, 18c and 18d allocated frequencies f_1, f_2, f_3 and f_4, respectively, and which employs neither frequency hopping nor frequency allocation swapping. The mapping of three logical channels (channel 1, channel 2 and channel 3) onto the physical channels represented by the timeslots 16 of the frames 14 for the carriers in the

cell is illustrated by the shading of timeslots. For example, channel 1 is allocated timeslot number T_2 on carrier 18a which transmits on frequency f_1. As can be seen in Figure 7, each timeslot number T_2 in the TDMA frames transmitted on carrier 18a carries data from logical channel 1. Similarly, logical channels 2 and 3 are allocated timeslots on carriers 18b and 18c (carrier frequencies f_2 and f_3 respectively) although they could as easily be allocated to physical channels corresponding to other timeslots on the carrier 18a to take advantage of the time division multiplexing of the TDMA frames.

Figure 8 is a diagrammatic illustration of data for transmission in a cell which employs slow frequency hopping over carrier frequencies f_1, f_2 and f_3. The frequency hopping is cyclic, with a cycle period of three TDMA frames. It can be seen, therefore, that in the first TDMA frame logical channel 1 is transmitted on frequency f_1, in the second TDMA frame using carrier frequency f_2, and in the third TDMA frame on frequency f_3. In the fourth TDMA frame, logical channel 1 is again transmitted on the carrier utilising frequency f_1.

Figure 9 shows one way of representing a cellular communications system in which both cyclic slow frequency hopping and frequency allocation swapping is employed by mapping logical channels onto physical channels. The cyclic period for the SFH is three TDMA frames, whilst the cyclic period for the FAS scheme is three SFH cycle periods, or nine TDMA frames.

Certain restrictions are imposed on carrier frequency allocations by GSM protocols. For example, in each cell in GSM there is one reserved carrier frequency in each cell, which is defined as the broadcast channel frequency (BCHF) and is the frequency on which the BCCH data are transmitted. On this carrier time slot T_0 is always used for the BCCH, and slow frequency hopping for this time slot is not permitted. The reason for this is that the mobile stations monitor the broadcast channels in surrounding cells and BCCH channel must be easily found. Also, a base transceiver station must transmit a burst in every time slot of every time frame in the downlink on the BCHF to allow mobiles to make power measurements of the radio frequency

channels supporting the BCCH. In order to achieve this requirement a dummy burst is transmitted in all time slots for which no other channel requires a burst to be transmitted on the BCHF. Therefore the GSM the broadcast channel frequency should be excluded from the frequency allocation swapping and the time slot T_0 on this carrier should be excluded from the slow frequency hopping.

As mentioned previously, it is not necessary for a slow frequency hopping scheme to employ all of the carrier frequencies available in a cell. Also, it is not necessary for frequency allocation swapping to employ all of the frequencies available in a cluster, nor is it necessary that all frequencies which are available for swapping within a cluster be swapped between cells at one time. Thus, for cyclic SFH and cyclic FAS the cyclic periods need not be tied to one another. Accordingly, by various combinations of SFH and FAS it is possible to arrange several different types of physical channels wherein certain timeslots use different numbers of frequencies to others.

Figure 10A represents two three-cell clusters in a GSM network, one cluster comprising cells A, B and C and the other cluster comprising cells A′, B′ and C′. The broadcast channel frequency for cells A and A′ is frequency f_0, for cells B and B′ the BCHF is f_3 and for cells C and C′ the BCHF is f_6. Therefore, in order to comply with the GSM requirement for a broadcast channel in timeslot T_0 in each TDMA frame, the broadcast channel frequency must be available for use of the first timeslot of every frame. The remaining available frequencies may be swapped at will between carriers within a cell and between cells within a cluster, and indeed the BCHF can be swapped as well so long as it is available at T_0 for each TDMA frame. This means that the various physical channels corresponding to different timeslots on the carriers in a cell may have different frequency hopping and frequency allocation swapping characteristics.

The arrows between cells A, B and C in Figure 10A show one way in which frequencies can be swapped within the cluster. The BCHFs f_0, f_3 and f_6 remain allocated in their respective cells whilst frequency f_1 is swapped from cell A to cell C, frequency f_7 passes from cell C to cell B, and frequency f_4 is swapped from cell B to cell A.

Figure 10B shows the next round of frequency swapping where the frequencies f_2, f_8 and f_5 are swapped amongst the cells A, C and B.

The table shown in Figure 11 sets forth a scheme for slow frequency hopping in cell A of the GSM network shown in Figure 10A, wherein frequency f_0 is the BCHF and frequencies f_1 and f_2 are the other two frequencies available for carriers in the cell. At timeslot T_0 in each TDMA frame only frequencies f_1 and f_2 are available for slow frequency hopping for traffic channels since f_0 is required for the broadcast control channel. However, for timeslots T_1 to T_7 all three frequencies f_0, f_1 and f_3 can be used for SFH of traffic channels to achieve better performance. In other words traffic channels which occupy time slots from T_1 to T_7 can have SFH over three carriers, while traffic channels which occupy time slot T_0 can have SFH over the two carriers f_1 and f_2 only, the BCHF frequency f_0 being used to transmit BCCH data. In cells B and C the situation is similar.

Considering now the application of frequency allocation swapping in the network of Figure 10A, the table shown in Figure 12 sets forth one way in which frequencies can be allocated amongst the cells in a cluster over the course of eight TDMA frames. In this network time slots from T_0 to T_7 can be allocated frequencies f_1, f_2, f_4, f_5, f_7 and f_8 and time slots from T_1 to T_7 can also be allocated frequencies f_0, f_3 and f_6 for traffic channels.

Three kinds of traffic channels can be organised:

- Channels without SFH
- Channels with SFH over carrier frequencies including the broadcast frequency.
- Channels with SFH over carrier frequencies excepting the broadcast frequency

The actual number of different channels of each kind may vary.

An example of channel distribution in a cell with three carriers 18a, 18b and 18c is shown in Figure 13. The broadcast channel frequency is f_0, and in timeslots T_0 to T_4

the other two carriers 18b and 18c swap from f_1 and f_2 to f_4, f_5, f_7 and f_8 in consecutive order, as in Table 12. Time slot T_0 at the frequency f_0 is used for the broadcast channel. Because every TDMA frame consists of eight time slots, 23 traffic channels can be organised in the cell with three carrier frequencies. Four out of seven traffic channels, which occupy time slots T_1 to T_4 at carrier f_0, are arranged without frequency hopping. The remaining 10 traffic channels which occupy time slots from T_0 to T_4 of the other two carriers, cannot use carrier frequency f_0 in the course of SFH and hence will hop over six frequencies: f_1, f_2, f_4, f_5, f_7 and f_8. The final nine traffic channels, which occupy time slots from T_5 to T_7 at all frequencies, can hop over seven from nine frequencies allocated in the cluster including f_0, the remaining two frequencies being constrained for the BCCH of the other two cells in the cluster. For the transceiver for the carrier operating at frequency f_0 that BCHF will be present in every time frame for time slots T_0 to T_4. However for time slots T_5 and T_7 that carrier can use the other two available frequencies in the cell in the second and third time frames. Yet at every third time frame, the carrier frequency of timeslots T_5 to T_7 will return to f_0, which restricts the possibilities of SFH. This does not provide much difference from cyclic SFH over three carriers and as a result these nine traffic channels can be treated as unaffected with the frequency allocation swapping.

Figure 16 shows frames 50, 52 and 54 generated by the three carriers 18a, 18b and 18c, respectively, at four different time instants, t_1, t_2, t_3 and t_4. The first portions 56 of the frames 50 to 54 represent time slots T_0 to T_4 and the carrier frequencies allocated thereto, and the second portions 58 of the frames 50 to 54 represent the time slots T_5 to T_7 and the frequencies allocated thereto. The time slots T_0 to T_4 of the first carrier 18a are always transmitted at the broadcast channel frequency f_0. Time slots T_0 to T_4 of the second and third carriers 18b and 18c cycle through the six available frequencies of a cluster, excluding the broadcast channel frequencies. Time slots T_5 to T_7, on the other hand, also use the broadcast channel frequency of a cell, f_0, and when one carrier is using f_0, the other two carriers respectively use the other two carrier frequencies available in the cell at that time. To fully cycle f_0 amongst the three carriers, the swapping method is such that for one carrier, time slots T_5 to T_7 will use f_0 every third frame. Therefore although the time slots T_5 to T_7 are able to use seven

frequencies in the cluster, effectively the benefit gained is the same as that gained by performing SFH over three frequencies because the broadcast channel frequency f_0 is used every third time frame.

As represented in Figure 13, three kinds of channels can be organised:

1. channels 30 which remain at one carrier frequency (the BCHF), of which there are shown four traffic channels as well as the BCCH;
2. channels 32, which swap over six frequencies within the cluster (excluding the BCHFs for the cluster), of which there are shown ten traffic channels; and
3. channels 34 which swap over three frequencies within the cell (including the BCHF for that cell), of which there are shown nine traffic channels.

The sets of channels in the cell under consideration for networks without FAS and with FAS is shown in the table of Figure 14. To compare the quality of these channels, the required Ec/No values for equal performance (6%, frame erasure rate (FER) at a MS velocity of V = 5 km/h) in these channels are also included. The quantity Ec/No relates to the ratio of the energy of an incoming signal to the power spectral density of noise in the signal, and is preferred in digital radio applications to a signal-to-noise ratio (SNR) measurement, since Ec/No values are independent of the receiver characteristics. It can be seen that by including frequency allocation swapping greater versatility is possible as compared with permanent channels allocation. Instead of a group of identical channels, FAS provides the network with a set of channels with different demands of the signal-to-noise ratio (or the actual reference sensitivity level) for equal quality of service. Because the mobile stations are distributed over the cell at different distances from the base station and the propagation conditions for mobiles are highly different too, by providing a number of channels with different characteristics it is possible to assign a MS to an appropriate channel, giving channels with lower required Ec/No values to those MS that are situated in worse conditions.

Also, the existence of a set of channels with different features creates some new possibilities in the intracell hand-over, with adaptive channel allocation depending on

the change of traffic, MS positioning, propagation conditions, etc. For this purpose it is also important that the channels distribution is not established permanently but can be changed dynamically, at every time frame.

The graph of Figure 15 shows a comparison between the quality of service available at various distances from the base station of a cell in the cases of no slow frequency hopping and no frequency allocation swapping, SFH without FAS, and with both SFH and FAS. The minimum quality of service (QoS) for communications within the cell is also indicated. In order to provide the best possible quality of service for all mobile stations in the cell at any one time, the physical channel for each MS can be allocated dynamically according to the QoS required. For example, referring to Figure 15, a MS which is within a distance d_1 of the BS can be allocated a channel without SFH and without FAS and still obtain a QoS greater than the required minimum. One of timeslots 30 without SFH, i.e. T_1 to T_4 of carrier f_0 shown in Figure 13, is appropriate for such a MS, although any of the other timeslots 32 and 34 could also be used since they all provide a better QoS. A mobile station at a distance between d_1 and d_2 will require at least one of timeslots 34, using SFH over three frequencies, for a minimum QoS although one of timeslots 32 could alternatively be employed if available. Mobile stations further than a distance d_2 from the BS will generally require the best quality channel available, i.e. one of timeslots 32 using SFH and FAS to hop over six frequencies, in order to achieve the minimum QoS.

It will be appreciated that the quality of transmissions on a particular channel will depend not only upon the distance of the mobile station from the base station, but also upon propagation losses of another nature, such as shadowing by buildings, diffraction of carriers, etc. This means that the QoS (as indicated by the SNR or Ec/No) may be low even for a mobile station which is quite close to the base station. Therefore, the QoS can only be considered as a pure function of the distance from the base station (Figure 15) in the case of radio wave propagation over free space.

In view of this, it is preferred that the selection of a channel for communication with a particular mobile station be based on some measurement of signal quality

characteristics between the mobile station and base station, rather than a measurement of the separation distance itself. According to GSM Recommendation 05.08 (Radio Sub-System Link Control) the base station measures every 480 msec a transmission parameter called "Received Signal Quality" (RXQUAL) which is expressed in terms of bit error rate (BER). Therefore, in implementing a system for channel allocation according to the present invention it is preferred to utilise the RXQUAL quantity in a threshold comparison to determine which class of channel should be allocated. If the BER of RXQUAL is higher than a given threshold then the mobile station should be allocated a channel with a lower required SNR value. Conversely, if the measured BER is lower than a given threshold then a channel with a higher required SNR is acceptable.

In general, the number of channels of every class will depend on the number of carrier frequencies in a cluster (N). If the number of traffic channels utilising only one frequency in a cell is "n", then it can be shown that:

the number of channels with SFH over all carriers available for swapping in the cluster is

$$(N - 1)*(n + 1),$$

the number of channels with SFH over frequencies allocated in the cell is

$$(7 - n)*N,$$

and the total amount of traffic channels in the cell is equal to 8N – 1.

It is considered reasonable to have n <= 7. Changing "n", it is possible to obtain the desired number of channels with better quality than in a network without frequency swapping.

It will be appreciated by those skilled in the art that, in GSM, signals transmitted from a base station to a mobile station (downlink) utilise a different frequency band than signals transmitted from a mobile station to a base station (uplink). Frequencies in each block are paired to form duplex carriers. It is envisaged that generally a system for swapping frequencies using SFH and/or FAS would involve both carriers in the duplex

to comply with GSM protocols, however, it will be recognised that the above communications method is applicable also to the case where the duplex carriers frequencies are swapped independently and/or individually and that one of the uplink or downlink can employ SFH and/or FAS whilst the other does not. Furthermore although the above description has concentrated primarily on cyclic swapping, SFH and FAS can also be implemented in a random manner as for random SFH.

CLAIMS:

1. A cellular telecommunications method for use in a cellular telecommunications network having at least one cluster of adjoining cells, including:

allocating respective control channel frequencies to said cells for transmitting a control channel in a cell;

allocating at least one other different frequency to each cell;

swapping between the frequencies allocated to said cells, except the control channel frequencies, for at least one traffic channel.

2. A cellular telecommunications method as claimed in claim 1, including swapping between the frequencies allocated to a cell for at least one other traffic channel.

3. A cellular telecommunications method as claimed in claim 2, including allocating the control channel frequency to at least one further traffic channel in a cell.

4. A cellular telecommunications method as claimed in claim 3, selectively allocating a call in one of said cells to said at least one traffic channel, said at least one other traffic channel or said at least one further traffic channel on the basis of transmission characteristics of said call.

5. A cellular telecommunications method as claimed in claim 4, wherein said transmission characteristics include the bit error rate for said call.

6. A cellular telecommunications method as claimed in claim 4, wherein said transmission characteristics include the distance of a mobile station for said call from a base station of said network.

7. A method as claimed in claim 1, wherein said swapping is synchronised between said cells to prevent co-channel interference.

8. A method as claimed in claim 1, wherein said channels are TDMA channels.

9. A method as claimed in claim 1, wherein said network is a GSM network.

10. A cellular telecommunications network having at least one cluster of adjoining cells, said cells each including:

a first transceiver for transmitting a control channel in a respective control channel frequency;

a second transceiver for transmitting at least one traffic channel at a different frequency allocated to the cell; and

control means for controlling said second transceiver to swap between the frequencies allocated to said cells, except the control channel frequencies, for said at least one traffic channel.

11. A cellular telecommunications network as claimed in claim 10, wherein said control means is adapted to control the first or second transceiver to swap between the frequencies allocated to the cell for at least one other traffic channel.

12. A cellular telecommunications network as claimed in claim 11, wherein said control means is adapted to control said first transceiver to transmit at least one further traffic channel at the control channel frequency in a cell.

13. A cellular telecommunications network as claimed in claim 12, wherein said control means selectively allocates a call in one of said cells to said at least one traffic channel, said at least one other traffic channel or said at least one further traffic channel on the basis of transmission characteristics of said call.

14. A cellular telecommunications network as claimed in claim 13, wherein said transmission characteristics include the bit error rate for said call.

15. A cellular telecommunications network as claimed in claim 13, wherein said transmission characteristics include the distance of a mobile station for said call from a base station of said network.

16. A network as claimed in claim 10, wherein said swapping is synchronised between said cells to prevent co-channel interference.

17. A network as claimed in claim 10, wherein said channels are TDMA channels.

18. A network as claimed in claim 10, wherein said network is a GSM network.

19. A cellular telecommunications method having signals for transmission within a cell organised in time division multiplexed channels, said method including transmitting first channels utilising a first number of transmission frequencies, and transmitting second channels using a second number of transmission frequencies.

20. A cellular telecommunications method as claimed in claim 19, including selecting the first or second channels for transmission of signals between a base station of said cell and a mobile station within said cell on the basis of transmission characteristics for said signals between the base station and the mobile station.

21. A cellular telecommunications method as claimed in claim 20, wherein said first channels are transmitted using an allocated broadcast channel frequency for the cell.

22. A cellular telecommunications method as claimed in claim 21, wherein said second channels are transmitted using a set of frequencies allocated to a cluster of adjoining cells including said cell which are swapped during transmission of the second channels.

23. A cellular telecommunications method as claimed in claim 22, including transmitting third channels using a third number of transmission frequencies, and selecting one of the first, second or third channels for transmission of said signals on the basis of said transmission characteristics.

24. A cellular telecommunications method as claimed in claim 23, wherein the third channels are transmitted using a subset of said set of frequencies allocated to said cell

and said broadcast channel frequency which are swapped during transmission of the third channels, and said subset is swapped between said cells.

25. A cellular telecommunications method as claimed in claim 24, wherein said transmission characteristics include the bit error rate for said call.

26. A cellular telecommunications method as claimed in claim 24, wherein said transmission characteristics include the distance of a mobile station for said call from a base station of said network.

27. A method as claimed in claim 19, wherein said swapping is synchronised between said cells to prevent co–channel interference.

28. A method as claimed in claim 19, wherein said channels are TDMA channels.

29. A method as claimed in claim 19, wherein said network is a GSM network.

30. A cellular telecommunications network including:

a cluster of cells having a set of transmission frequencies; and

a base station in each cell of said cluster adapted for transmission of signals on first channels within the cell using a first number of said frequencies and on second channels within the cell using a second number of said frequencies.

31. A cellular telecommunications network as claimed in claim 30, wherein said base station includes means for selecting the first or second channels for transmission of signals between said base station and a mobile station within the cell on the basis of transmission characteristics of said signals.

32. A cellular telecommunications network as claimed in claim 31, wherein said first channels are transmitted using an allocated broadcast channel frequency for the cell.

33. A cellular telecommunications network as claimed in claim 32, wherein said

second channels are transmitted using a set of frequencies allocated to a cluster of adjoining cells including said cell which are swapped during transmission of the second channels.

34. A cellular telecommunications network as claimed in claim 33, wherein said base station is adapted to transmit third channels using a third number of transmission frequencies, and said selecting means selects one of the first, second or third channels for transmission of said signals on the basis of said transmission characteristics.

35. A cellular telecommunications network as claimed in claim 34, wherein the third channels are transmitted using a subset of said set of frequencies allocated to said cell and said broadcast channel frequency which are swapped during transmission of the third channels, and said subset is swapped between said cells.

36. A cellular telecommunications network as claimed in claim 35, wherein said transmission characteristics include the bit error rate for said call.

37. A cellular telecommunications network as claimed in claim 35, wherein said transmission characteristics include the distance of a mobile station for said call from said base station.

38. A network as claimed in claim 30, wherein said swapping is synchronised between said cells to prevent co-channel interference.

39. A network as claimed in claim 30, wherein said channels are TDMA channels.

40. A network as claimed in claim 30, wherein said network is a GSM network.

41. A cellular telecommunications method as claimed in claim 23, wherein the quality of said second channels is greater than the quality of said third channels which is greater than the quality of said first channels.

42. A cellular telecommunications network as claimed in claim 34, wherein the quality of said second channels is greater than the quality of said third channels which is greater than the quality of said first channels.

43. A cellular telecommunications method as claimed in claim 4, wherein the quality of said at least one traffic channel is greater than the quality of said at least one other traffic channel and is greater than the quality of said at least one further traffic channel.

44. A cellular telecommunications network as claimed in claim 13, wherein the quality of said at least one traffic channel is greater than the quality of said at least one other traffic channel and is greater than the quality of said at least one further traffic channel.

45. A cellular telecommunications method for use in a cellular telecommunications network having at least one cluster of adjoining cells, said cells being allocated different respective sets of different transmission frequencies, said method including:

intracell frequency hopping by swapping the allocated frequencies within said cells; and

intercell frequency allocation swapping by swapping said sets of frequencies between the cells.

46. A cellular telecommunications network including at least one cluster having adjoining cells provided by corresponding base stations, said cells being allocated different respective sets of different transmission frequencies and the base stations having control means for controlling intracell frequency hopping by swapping the allocated frequencies within said cells, and controlling intercell frequency allocation swapping by swapping said sets of frequencies between the cells.

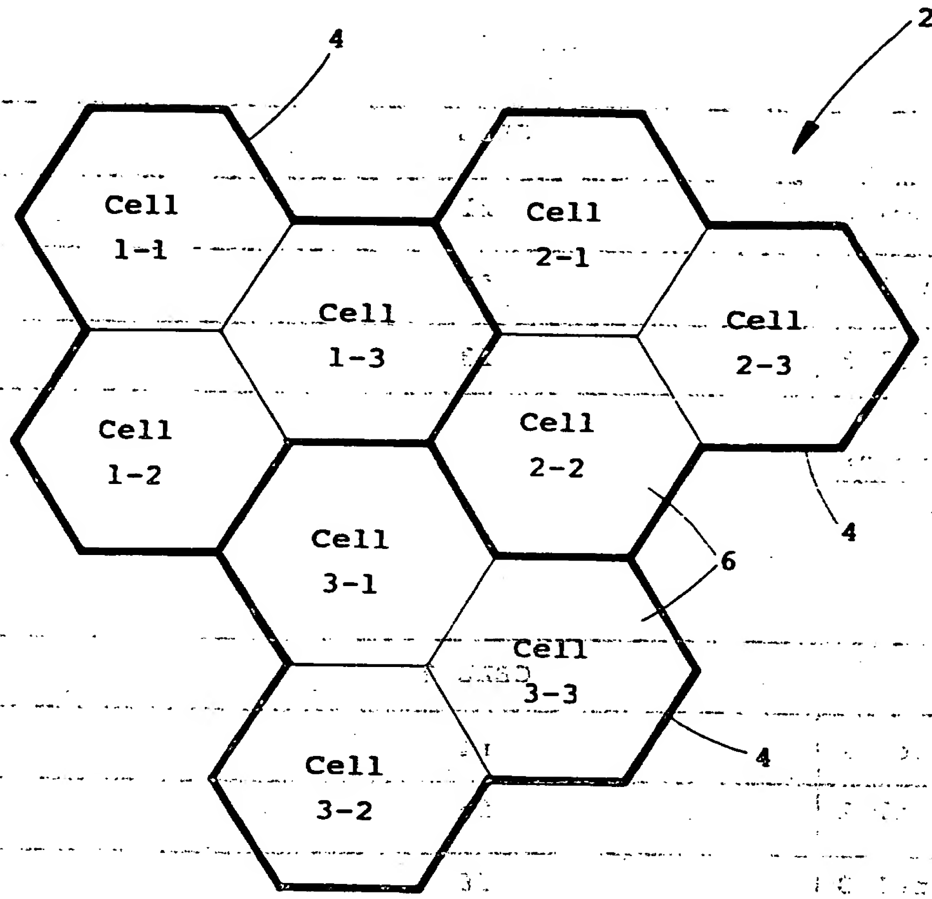


FIGURE 1

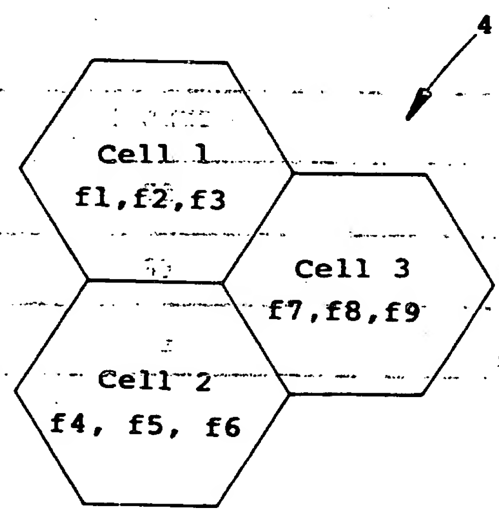


FIGURE 2

CELL 1	
Channel 1	f1
Channel 2	f2
Channel 3	f3

FIGURE 3A

CELL 2	
Channel 1	f4
Channel 2	f5
Channel 3	f6

FIGURE 3B

CELL 3	
Channel 1	f7
Channel 2	f8
Channel 3	f9

FIGURE 3C

CELL 1												
	SFH CYCLE 1			SFH CYCLE 2			SFH CYCLE 3			SFH CYCLE 4		
CHANNEL 1	f1	f2	f3	f1	f2	f3	f1	f2	f3	f1	f2	f3
CHANNEL 2	f2	f3	f1	f2	f3	f1	f2	f3	f1	f2	f3	f1
CHANNEL 3	f3	f1	f2	f3	f1	f2	f3	f1	f2	f3	f1	f2

FIGURE 4A

CELL 2												
	SFH CYCLE 1			CYCLE 2			CYCLE 3			CYCLE 4		
CHANNEL 1	f4	f5	f6	f4	f5	f6	f4	f5	f6	f4	f5	f6
CHANNEL 2	f5	f6	f4	f5	f6	f4	f5	f6	f4	f5	f6	f4
CHANNEL 3	f6	f4	f5	f6	f4	f5	f6	f4	f5	f6	f4	f5

FIGURE 4B

CELL 3												
	SFH CYCLE 1			CYCLE 2			CYCLE 3			CYCLE 4		
CHANNEL 1	f7	f8	f9	f7	f8	f9	f7	f8	f9	f7	f8	f9
CHANNEL 2	f8	f9	f7	f8	f9	f7	f8	f9	f7	f8	f9	f7
CHANNEL 3	f9	f7	f8	f9	f7	f8	f9	f7	f8	f9	f7	f8

FIGURE 4C

CELL 1												
	SFH CYCLE 1			SFH CYCLE 2			SFH CYCLE 3			SFH CYCLE 4		
CHANNEL 1	f1	f2	f3	f4	f5	f6	f7	f8	f9	f1	f2	f3
CHANNEL 2	f2	f3	f1	f5	f6	f4	f8	f9	f7	f2	f3	f1
CHANNEL 3	f3	f1	f2	f6	f4	f5	f9	f7	f8	f3	f1	f2

FIGURE 5A

CELL 2												
	SFH CYCLE 1			CYCLE 2			CYCLE 3			CYCLE 4		
CHANNEL 1	f4	f5	f6	f7	f8	f9	f1	f2	f3	f4	f5	f6
CHANNEL 2	f5	f6	f4	f8	f9	f7	f2	f3	f1	f5	f6	f4
CHANNEL 3	f6	f4	f5	f9	f7	f8	f3	f1	f2	f6	f4	f5

FIGURE 5B

CELL 3												
	SFH CYCLE 1			CYCLE 2			CYCLE 3			CYCLE 4		
CHANNEL 1	f7	f8	f9	f1	f2	f3	f4	f5	f6	f7	f8	f9
CHANNEL 2	f8	f9	f7	f2	f3	f1	f5	f6	f4	f8	f9	f7
CHANNEL 3	f9	f7	f8	f3	f1	f2	f6	f4	f5	f9	f7	f8

FIGURE 5C

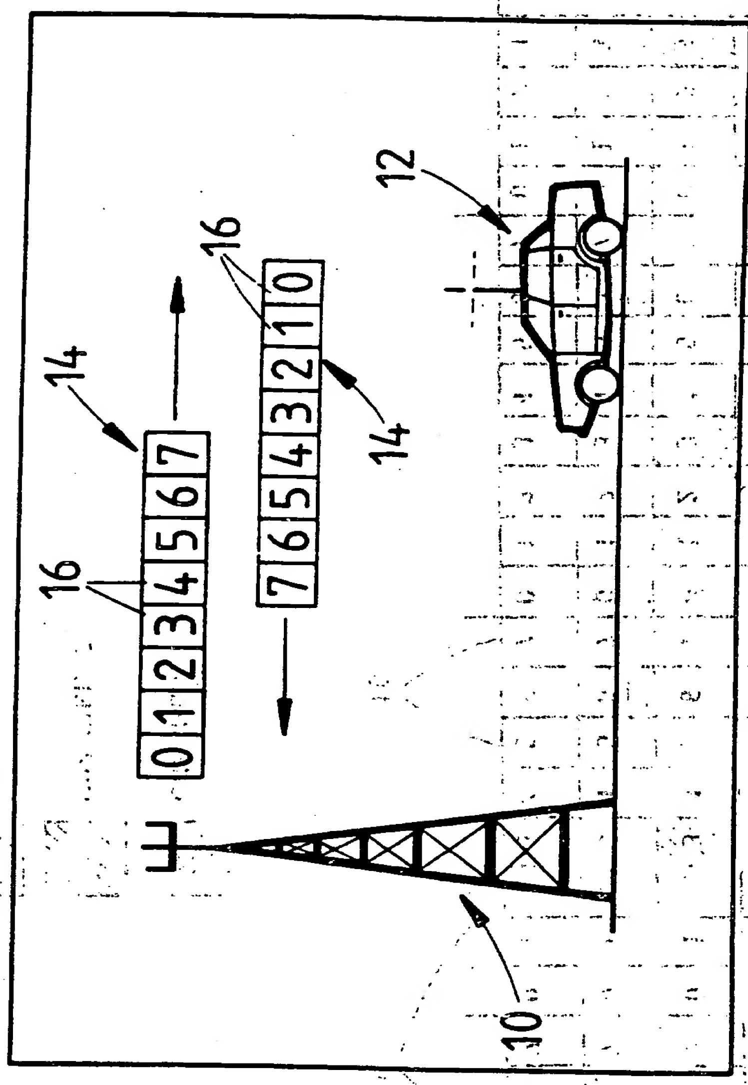


FIG 6

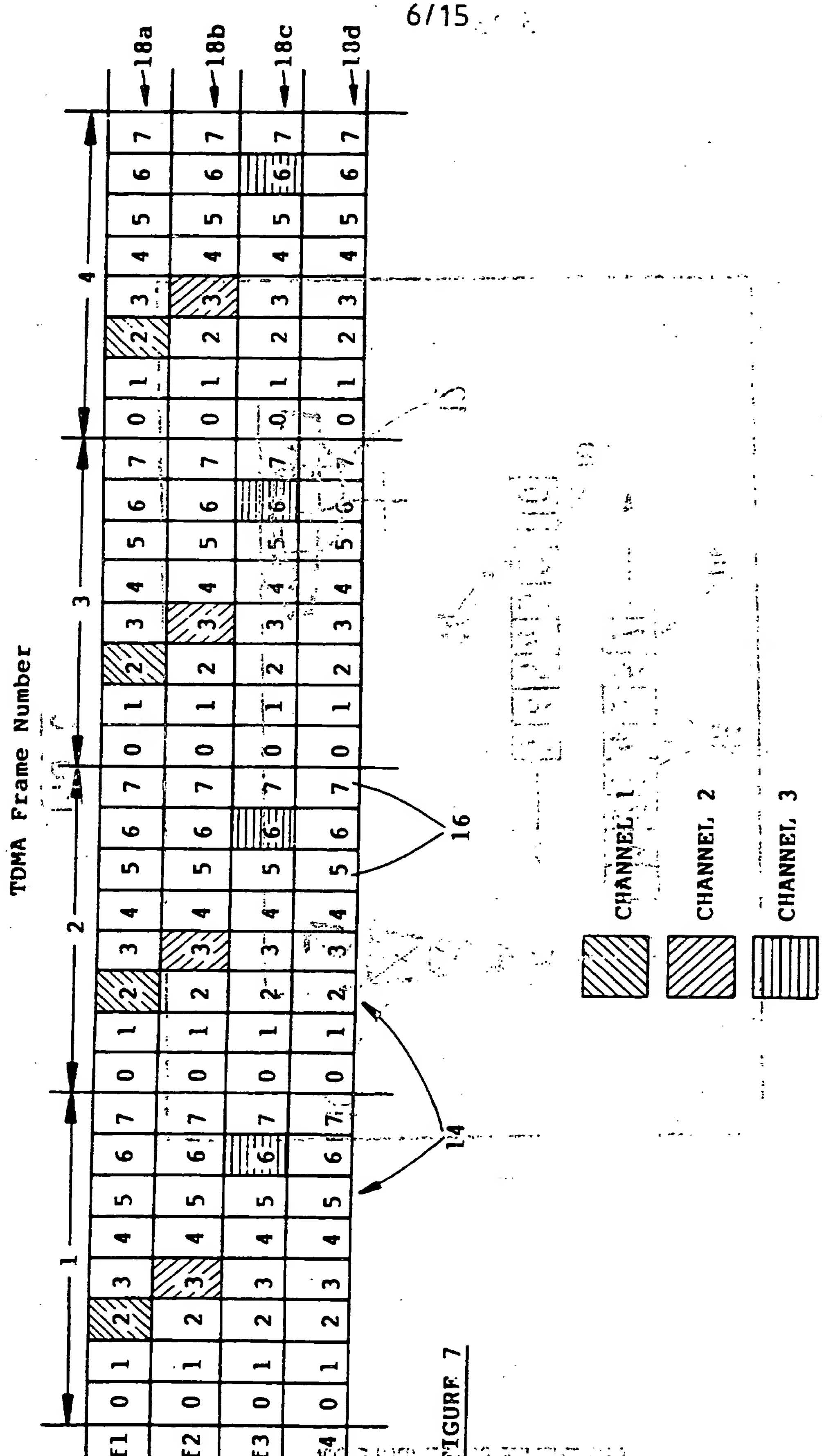

TDMA Frame Number
1
2
3
4
18a
18b
18c
18d
f1
f2
f3
f4
0 1 2 3 4 5 6 7
14
16
CHANNEL 1
CHANNEL 2
CHANNEL 3

FIGURE 7

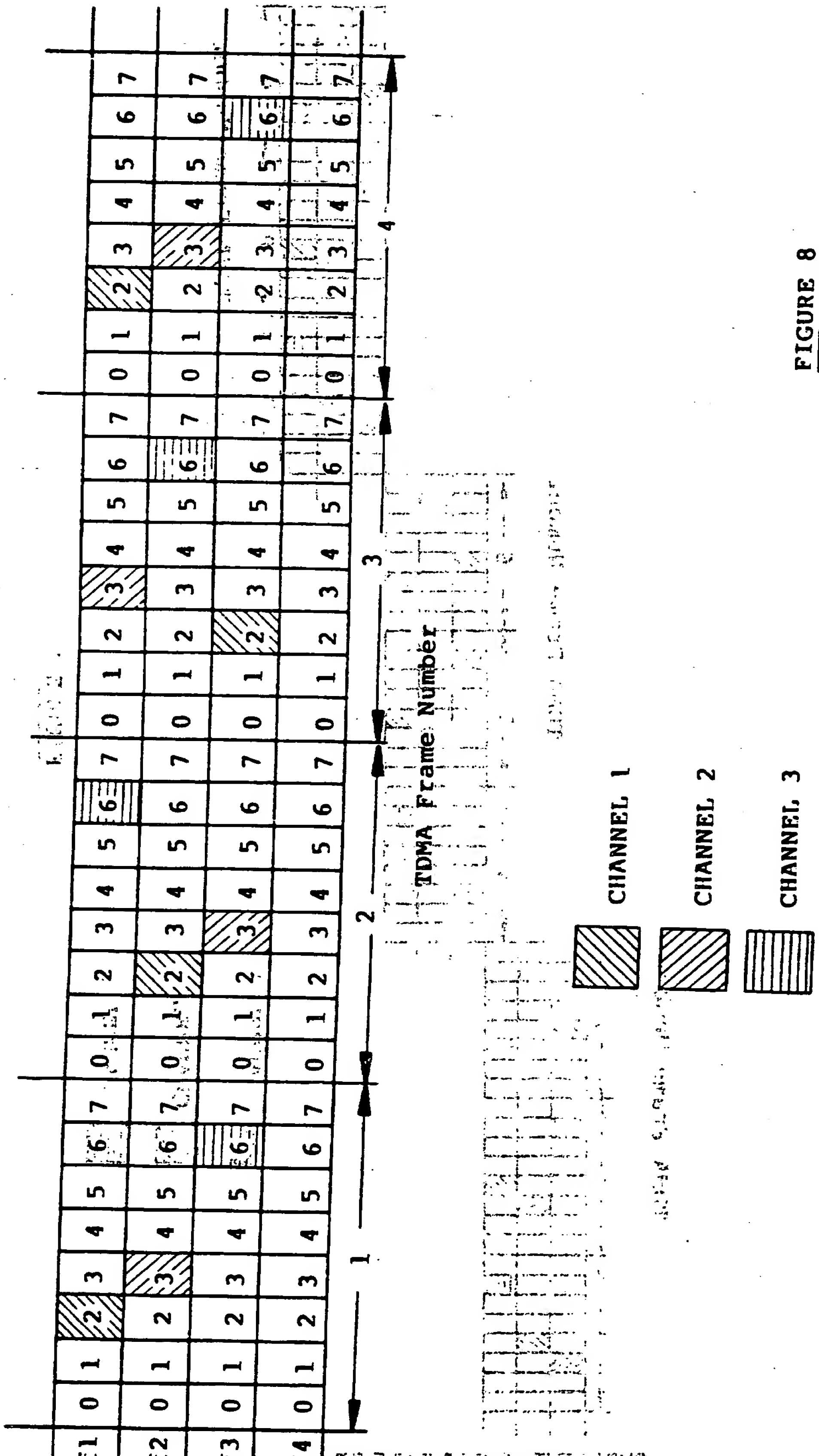

f1
f2
f3
f4
0 1 2 3 4 5 6 7
1
2
3
4
TDMA Frame Number
CHANNEL 1
CHANNEL 2
CHANNEL 3

FIGURE 8

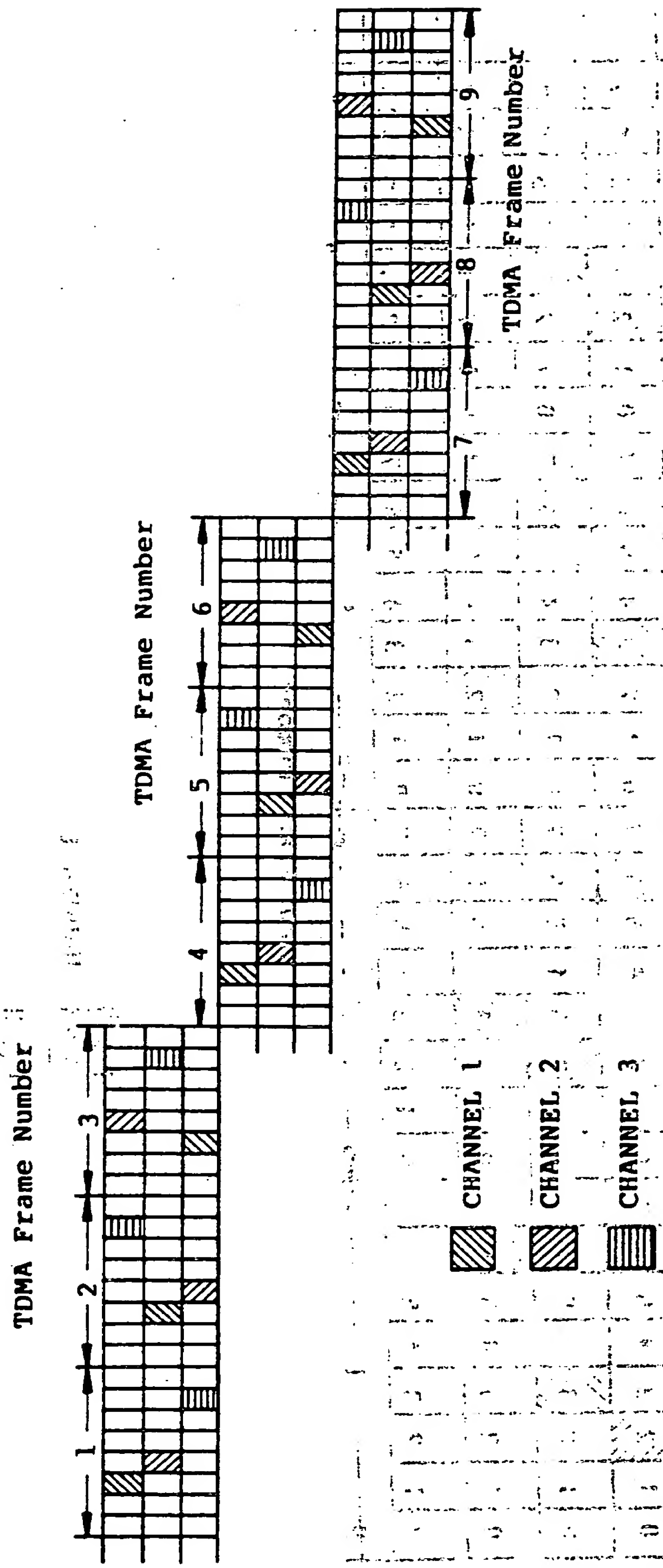


FIGURE 9

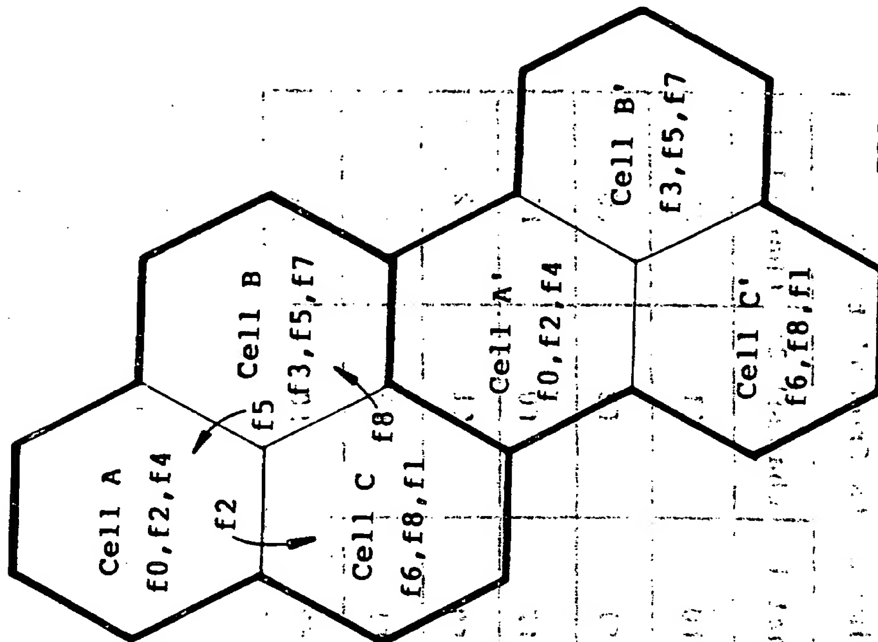


FIGURE 10b

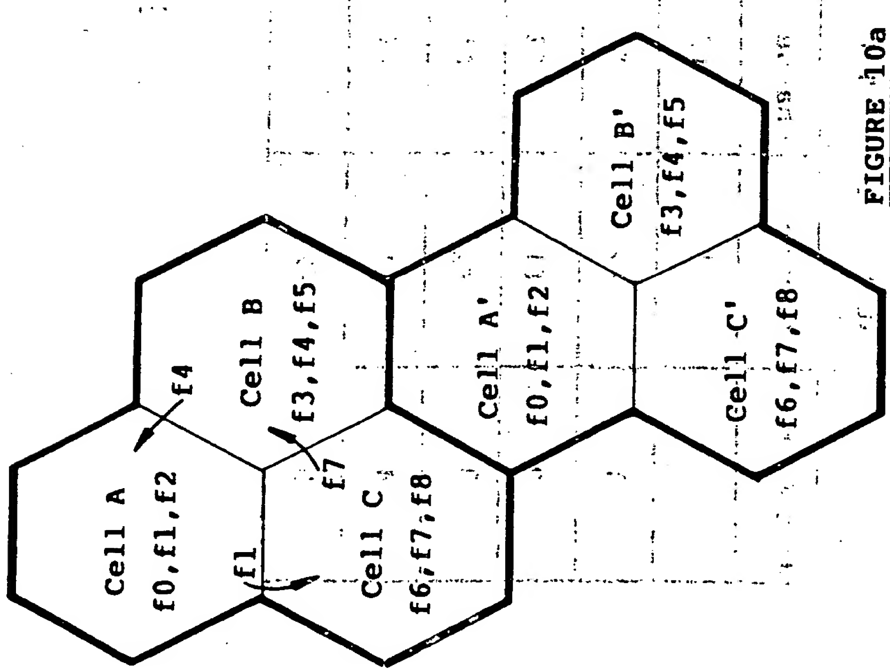


FIGURE 10a

Time Frames	At time slot T0		At time slots from T1 to T7		
	Channel 1	Channel 2	Channel 1	Channel 2	Channel 3
0	f1	f2	f0	f1	f2
1	f2	f1	f1	f2	f0
2	f1	f2	f2	f0	f1
3	f2	f1	f0	f1	f2
4	f1	f2	f1	f2	f0
5	f2	f1	f2	f0	f1

FIGURE 11

Time Frame		Cell A		Cell B			Cell C		
0	f0	f1	f2	f3	f4	f5	f6	f7	f8
1	f0	f2	f4	f3	f5	f7	f6	f8	f1
2	f0	f4	f5	f3	f7	f8	f6	f1	f2
3	f0	f5	f7	f3	f8	f1	f6	f2	f4
4	f0	f7	f8	f3	f1	f2	f6	f4	f5
5	f0	f8	f1	f3	f2	f4	f6	f5	f7
6	f0	f1	f2	f3	f4	f5	f6	f7	f8
7	f0	f2	f4	f3	f5	f7	f6	f8	f1
8	f0	f4	f5	f3	f7	f8	f6	f1	f2

FIGURE 12

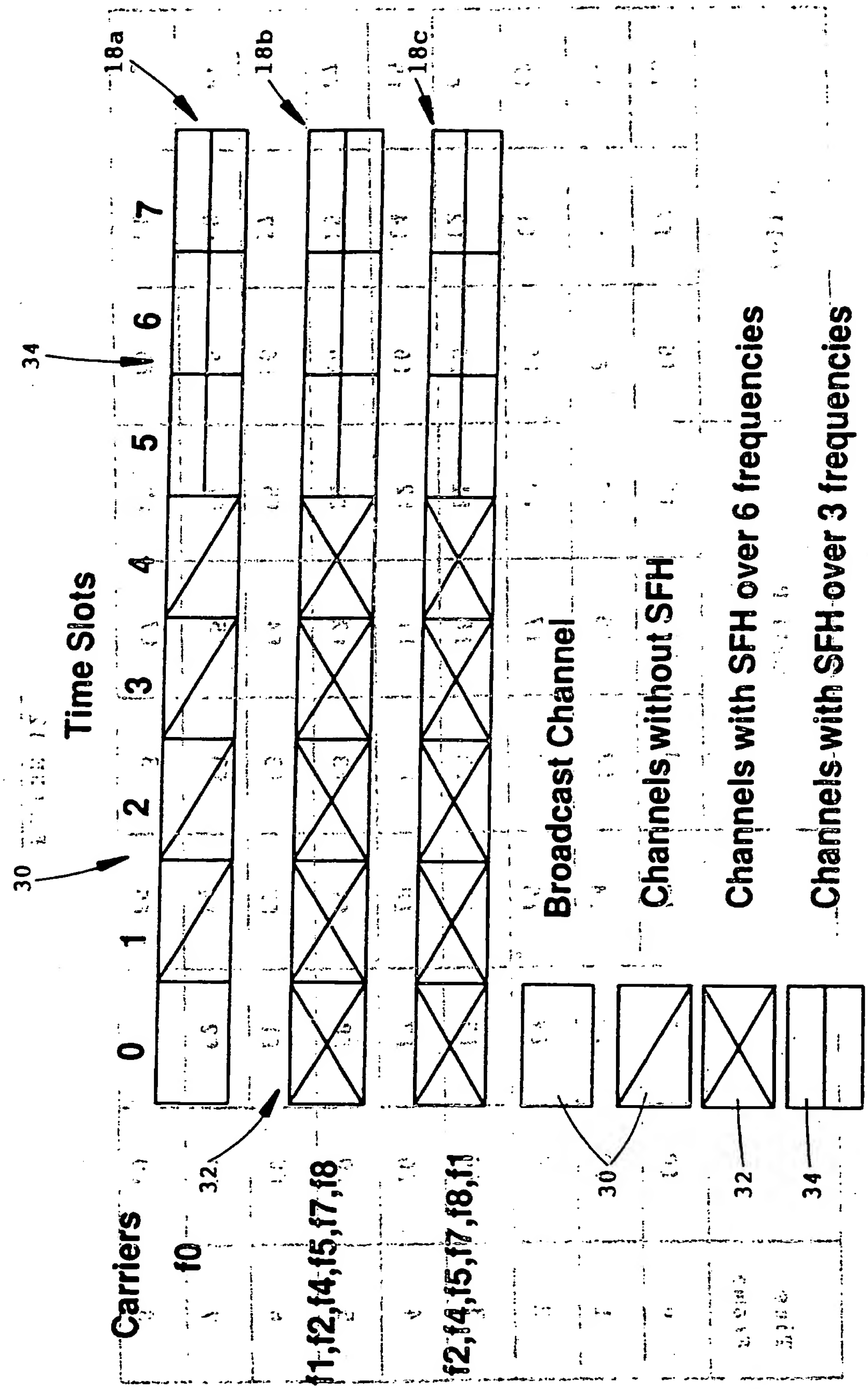
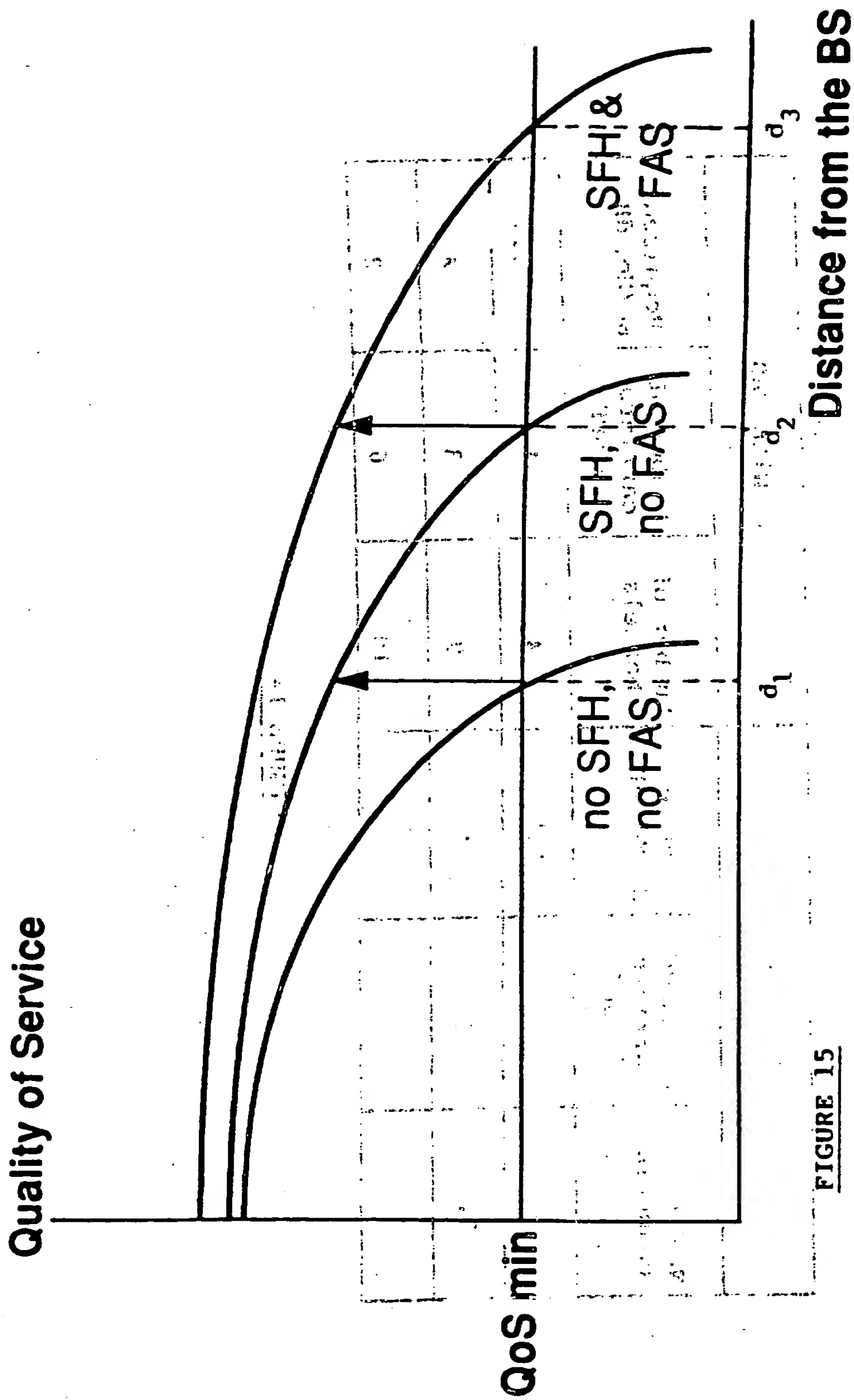

Time Slots
0
1
2
3
4
5
6
7
Carriers
f0
f1,f2,f4,f5,f7,f8
f2,f4,f5,f7,f8,f1
18a
18b
18c
30
32
34
Broadcast Channel
Channels without SFH
Channels with SFH over 6 frequencies
Channels with SFH over 3 frequencies

FIGURE 13

No FAS			With FAS		
Number of channels	Number of carriers in SFH	Required Ec/No, dB	Number of channels	Number of carriers in SFH	Required Ec/No, dB
2	2	6.5	4	1	8.5
21	3	4	9	3	4
			10	6	2

FIGURE 14



Quality of Service
QoS min
Distance from the BS
no SFH, no FAS
SFH, no FAS
SFH & FAS
d1
d2
d3

FIGURE 15

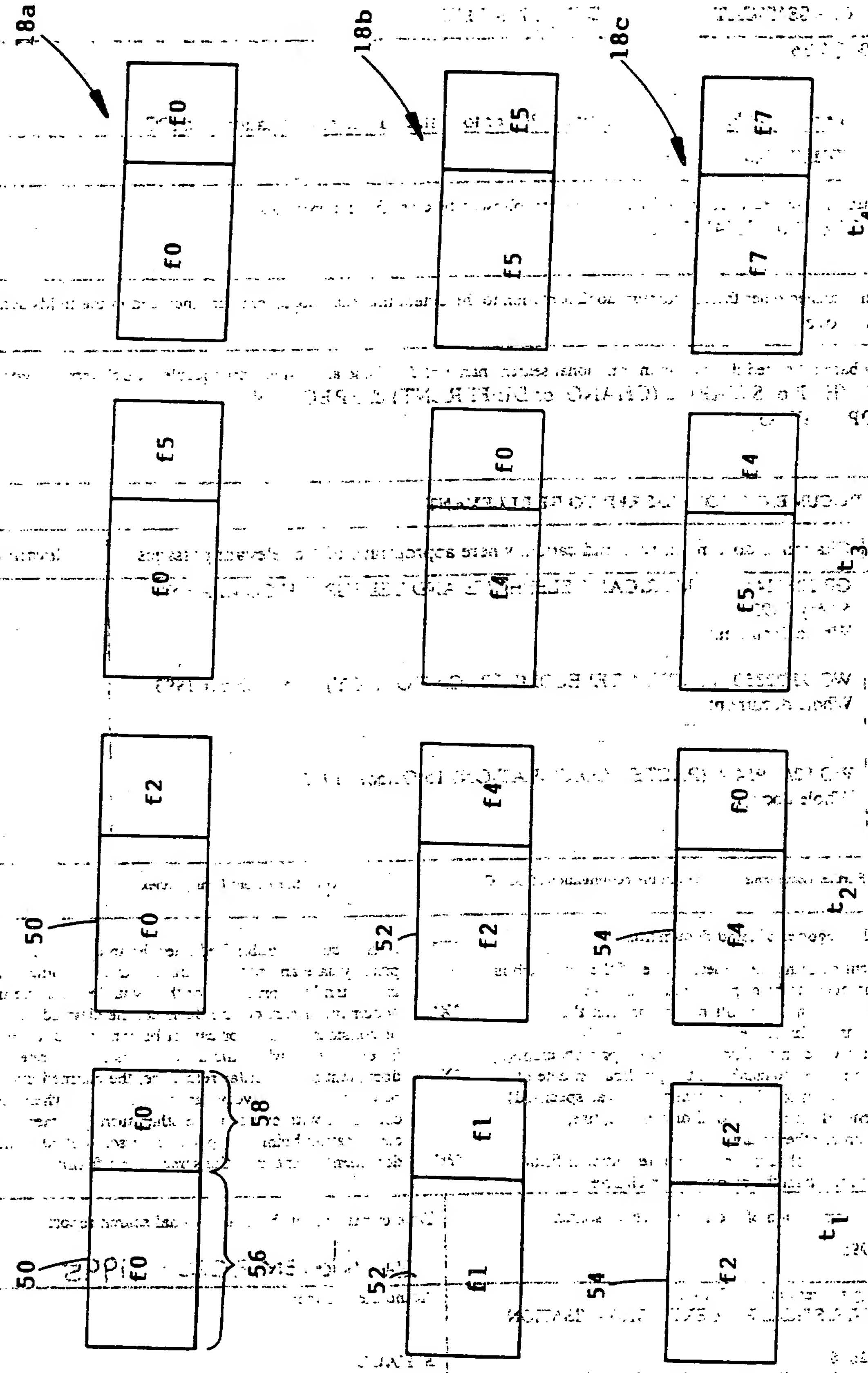

18a
18b
18c
f0
f0
f5
f5
f7
f7
t4
f5
f0
f0
f4
f4
f5
t3
f2
f0
f4
f2
f0
f4
t2
50
52
54
f0
f0
f1
f1
f2
f2
t1
58
56
50
52
54

FIGURE 16

INTERNATIONAL SEARCH REPORT

International Application No.
PCT/AU 95/00561

A. CLASSIFICATION OF SUBJECT MATTER

Int Cl[6]: H04Q 7/36

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC: H04Q 7/36, 7/04; H04B 7/26

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
AU: IPC as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
DERWENT: (HOP or SWAP) & (CHANG: or DIFFERENT) & FREQUENC:
JAPIO: HOP or SWAP

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	GB 2261141 A (AMERICAN TELEPHONE AND TELEGRAPH COMPANY) 5 May 1993 Whole document	
A	WO 93/22850 A (NOKIA TELECOMMUNICATIONS OY) 11 November 1993 Whole document	
A	WO 92/17954 A (PACTEL CORPORATION) 15 October 1992 Whole document	

[X] Further documents are listed in the continuation of Box C

[X] See patent family annex

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 November 1995	29 NOVEMBER 1995

Name and mailing address of the ISA/AU	Authorized officer
AUSTRALIAN INDUSTRIAL PROPERTY ORGANISATION PO BOX 200 WODEN ACT 2606 AUSTRALIA Facsimile No.: (06) 285 3929	S. KAUL Telephone No.: (06) 283 2182

INTERNATIONAL SEARCH REPORT

International Application No.
PCT/AU 95/00561

C (Continuation)	DOCUMENTS CONSIDERED TO BE RELEVANT	
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Patent Abstracts of Japan, E 1072, page 90, JP 3-58530 A (NEC CORP) 13 March 1991 Abstract	
A	WO 91/13521 A (MOTOROLA INC) 5 September 1991 Whole document	
A	WO 91/13502 A (MOTOROLA INC) 5 September 1991 Whole document	
A	Derwent Abstract Accession No. 90-285745/38, class W02, JP 02-200024 A (NIPPON TELEG & TELEPH) 8 August 1990 Abstract	

INTERNATIONAL SEARCH REPORT
Information on patent family members

International Application No.
PCT/AU 95/00561

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member			
GB	2261141	CA	2081794	US	5323447

END OF ANNEX